Indirect Rotational Spectroscopy of Astronomically Relevant Molecular Ions

Completed Technology Project (2016 - 2017)

Project Introduction

The objective of this proposal is to obtain high-precision rotational spectra of H2D+, D2H+, and H2O+ indirectly through rovibrational spectroscopy. This will support future observations with the Stratospheric Observatory for the Far Infrared (SOFIA) and improve the interpretation of H2O+ data from the Herschel Space Observatory. Molecular ions play an important role in the chemistry and evolution of the interstellar medium (ISM). Although ions only account for a small percentage of species within the ISM, they drive the chemistry through reactions with neutral molecules, which are able to overcome the low concentrations and temperatures of interstellar space. Ion chemistry can be initiated when cosmic rays ionize molecular hydrogen, the most abundant species the ISM. This leads to the formation of H3+, which has a low proton affinity and can easily protonate neutral molecules. This initiates a chain of ion-neutral reactions which produces the rich chemistry observed in the ISM. The molecules which form allow the interstellar gas to cool and condense into star-forming regions, making H3+ particularly important to the formation of stars and planets. However, H3+ can only be observed by its rovibrational transitions. In regions without the necessary infrared background, molecules which have rotational spectra must be used to trace H3+ or probe cosmic conditions. In cold regions where deuterium fractionation occurs, H2D+ and D2H+ exist in high enough abundances to have their THz spectra observed by missions like SOFIA and act as useful tracers of H3+. However, many transitions of H2D+ and D2H+ which have yet to be observed and have large uncertainties in their predicted rotational transitions. In warmer regions, the molecular ion H2O+ can act as a probe of interstellar conditions, such as the cosmic ray ionization rate and the molecular hydrogen fraction. However, the field free rotational transition frequencies of H2O+ were extrapolated from laser magnetic resonance, and a number of them have significantly disagreed with astronomical observations. High-precision field free measurements could be used to reevaluate past data from the Herschel Space Observatory. The method Noise Immune Cavity Enhanced Optical Heterodyne Velocity Modulation Spectroscopy (NICE-OHVMS) has successfully investigated a number of molecular ions in the mid-infrared (mid-IR). However, in order to obtain high-precision rovibrational spectra of H2D+, D2H+, and H2O+, the sensitivity and resolution of the technique must be improved. This can be accomplished by up-converting the light to a shorter wavelength after it interacts with the sample. This allows for faster and more responsive detectors and will enable large high-precision surveys that can be used to predict THz rotational transitions with higher precision than what was previously possible. These values will then assist future searches with SOFIA and help reevaluate past data from the Herschel Space Observatory. This will lead to a deeper understanding of interstellar chemistry and how stars and planets form from the interstellar medium.

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Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Astrophysics

Project Management

Program Manager:

Joe Hill-kittle

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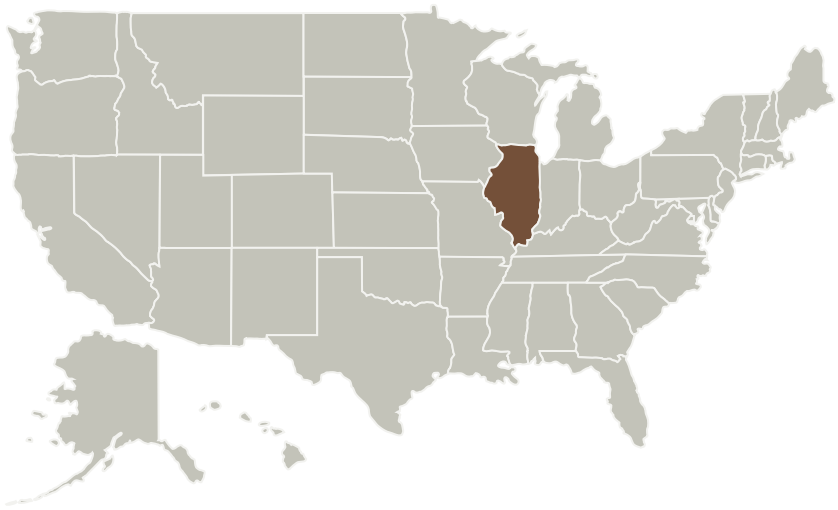
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Illinois at Urbana-Champaign	Supporting Organization	Academia	Urbana, Illinois

Primary U.S. Work Locations
Illinois

Project Management *(cont.)*

Principal Investigator:

Benjamin J Mccall

Co-Investigators:

Stephanie L Fellmann
Charles R Markus

Technology Areas

Primary:

- TX08 Sensors and Instruments
  - TX08.3 In-Situ Instruments and Sensors
    - TX08.3.2 Atomic and Molecular Species Assessment

Target Destination

Outside the Solar System